



TOGETHER
for a sustainable future

OCCASION

This publication has been made available to the public on the occasion of the 50th anniversary of the United Nations Industrial Development Organisation.



TOGETHER
for a sustainable future

DISCLAIMER

This document has been produced without formal United Nations editing. The designations employed and the presentation of the material in this document do not imply the expression of any opinion whatsoever on the part of the Secretariat of the United Nations Industrial Development Organization (UNIDO) concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries, or its economic system or degree of development. Designations such as “developed”, “industrialized” and “developing” are intended for statistical convenience and do not necessarily express a judgment about the stage reached by a particular country or area in the development process. Mention of firm names or commercial products does not constitute an endorsement by UNIDO.

FAIR USE POLICY

Any part of this publication may be quoted and referenced for educational and research purposes without additional permission from UNIDO. However, those who make use of quoting and referencing this publication are requested to follow the Fair Use Policy of giving due credit to UNIDO.

CONTACT

Please contact publications@unido.org for further information concerning UNIDO publications.

For more information about UNIDO, please visit us at www.unido.org

22903

cc to hull



US/CPR/96/108

C. 2000/030

Case Study on Development of Circulating Fluidized-bed Combustion Boiler Technology in China

Final Report

Prepared for:

Subproject "Technology Output" of UNIDO Project US/CPR/96/108 -
"Evaluation and Adjustment of China's Sustainable Industrial Planning and Policies"
United Nations Industrial Development Organisation (UNIDO)

Prepared by:

Mr. Shi Han
Center for Environmentally Sound Technology Transfer
The Administrative Center for China's Agenda 21
Email: hanshi@hotmail.com

Mr. Ma Chi
National Research Center for Science and Technology for Development
Ministry of Science and Technology
People's Republic of China

Beijing, May 2002

EXECUTIVE SUMMARY

In the course of carrying out Subproject "Technology Output" of UNIDO Project US/CPR/96/108 - "Evaluation and Adjustment of China's Sustainable Industrial Planning and Policies", it was found that there has been few empirical studies on how Chinese enterprises determine their technology selection, and how it is affected by government policies and programs aimed at increasing industrial uptakes of EST. For this purpose, it is proposed that the subproject would be extended with a case study involving interviews at the enterprise level and intensive discussions with government agencies and R&D institutions. This would provide additional and new information that will be very useful for the design of a better-focused, more practical technology policy.

The case study would focus on a carefully selected sector, which itself has a clear boundary but influences a wide range of other industrial sectors. The boiler sector (including both utility and industrial boilers) was selected for the case study because boilers have been widely used in many industrial sectors as intermediate products. Any technological improvement in the boiler manufacture sector can lead to significant improvement of energy efficiency and environmental performance across a wide range of sectors.

Researchers for the case study interviewed twelve boiler manufacturers (including 8 out of the 9 leading boiler manufacturers in China), five leading CFBC boiler technology research institutes, five government agencies, one industrial association and three end users.

Although China started to develop the bubbling fluidized-bed combustion technology in the 1960s, China lags behind in the development and production of larger scale CFBC boilers. International companies, such as FWC, dominate China's large CFBC boiler market.

Findings from interviews with China's CFBC boiler manufacturers include:

- Government energy and environmental policies started to affect industrial decisions on technology selection and implementation. However, there are some problems to be solved for these policies and regulations to play their full role.
- Chinese boiler manufacturers lack in-plant R&D capability and primarily rely on external sources of CFBC technologies.
- Policy barriers remain bottlenecking the further growth of the market for CFBC boilers in China.
- Leading international companies still dominate the large-scale CFBC boiler (with capacity 220 tph or above) market in China but Chinese domestically developed CFBC technologies have become more competitive for small CFBC (130 tph and below) boiler market.
- Irrational industrial structure and over-heated market competition have undermined the profitability and in turn technology innovation capacity of Chinese boiler manufacturers. However, some Chinese boiler manufacturers

started to react to this challenge by enhancing their in-plant technological capacity via internal organizational transformation and correcting incentive.

- Domestic boiler manufacturers lack access to government policies, financial support and technical information that they used to enjoy. Meanwhile, government has not provided alternative support measures in line with the market economic system such as tax exemption for technological innovation.

Findings from Interviews with China's CFBC Technology Developers include:

- Leading CFBC technology R&D capabilities reside in universities, Chinese Academy of Sciences, and research institutes affiliated with the State Power Corporation. None of them is affiliated with any boiler manufacturers. In many ways, the limited R&D resources are fragmented and lack of coordination and cooperation among them.
- Domestic universities and research institutes have been driven downstream along the technology innovation chain. They assume more CFBC technology dissemination role rather than concentrated on basic theoretic research to underpin the development of CFBC technology.
- Domestic R&D on CFBC technology has been substantially under-funded as compared to the monies spent on licensing of foreign CFBC technologies. In particular, domestic developed technologies lack means of commercialization through demonstration projects.
- At current, the synergy between different government programs has been little. The link between CFB technology R&D activities and technology importation remains missing.
- Emerging means of strategic technology alliance between domestic boiler manufacturers and research institutes/universities.

On the basis of the above-listed findings, we propose the following policy recommendations:

- Better coordination and synergy between government agencies, particularly the SDPC, SETC, MOST and SEPA, will be crucial to maximize the effects of government policies and programs with regard to China's CFBC technology development.
- It is suggested that government would provide objective, timely information and opener access to government policy and regulation formulation process to China's boiler manufacturers, especially those smaller boiler works.
- It is essential to proactively facilitate the restructuring of China's boiler manufacturing sector.
- Dismantling the local protectionism and fostering the formation of nationwide market for environmentally sound boilers have proven to be preconditions for rational industrial transformation.
- To survive in the fierce global competition, it is vital to vigorously foster strategic alliance and cooperation between leading domestic CFBC technology developers and boiler manufacturers.
- It is crucial to improve policy formulation, implementation and evaluation process on a continuous basis by adopting a more participatory policy

formulation process and enhancing the monitoring and evaluation of policy implementation.

At last, we specifically recommend that the technology and environmental policies focus on:

- Substantially increasing the government support to R&D and demonstration activities for CFBC and other clean coal technologies.
- Promoting the local development, demonstration and commercialization of smaller, low cost CFBC boiler technology with a capacity up to 410 tph. China's chances of developing technology for large CFBC boilers are small. Therefore, the scarce governmental resources should not be "wasted" on the development of technology for large CFBC boilers. The governmental support should be focused on a limited number of "viable" projects.
- Increasing the diffusion of CFBC boilers. The technology polices should aim to reduce the cost of production through increased absorption of imported technology and indigenization of production and improvement of domestic CFBC technology. Environmental polices should focus on enforcement of regulations, which would create a demand for CFBC boilers and other EST.
- More concerned government efforts in scaling up the indigenous CFBC boiler technology and importing advanced international technology.
- Promoting strategic alliance and cooperation between leading CFBC technology developers and boiler manufacturers.

TABLE OF CONTENTS

TABLE OF CONTENTS	IV
SECTION 1: INTRODUCTION	1
1.1 BACKGROUND OF THE CASE STUDY.....	1
1.2 RATIONAL FOR SELECTING CFBC TECHNOLOGY AS THE SUBJECT OF THE CASE STUDY.....	1
1.3 OBJECTIVES OF THE CASE STUDY.....	3
1.4 PROCESS OF THE CASE STUDY.....	3
1.5 STRUCTURE OF THE REMAINING PAPER.....	4
SECTION 2: OVERVIEW OF CFBC BOILER TECHNOLOGY DEVELOPMENT WORLDWIDE AND IN CHINA	5
2.1 REVIEW OF CFBC TECHNOLOGY DEVELOPMENT WORLDWIDE.....	5
2.2 REVIEW OF CURRENT STATUS OF CFBC TECHNOLOGY DEVELOPEMNT IN CHINA.....	7
SECTION 3: FINDINGS OF INTERVIEWS	10
3.1 FINDINGS FROM INTERVIEWS WITH CHINA’S CFBC BOILER MANUFACTURERS.....	10
3.2 FINDINGS FROM INTERVIEWS WITH CHINA’S CFBC TECHNOLOGY DEVELOPERS.....	16
SECTION 4: POLICY RECOMMENDATIONS	21
4.1 BETTER COORDINATION AND SYNERGY BETWEEN GOVERNMENT AGENCIES.....	21
4.2 FACILITATING THE RESTRUCTURING OF CHINA’S BOILER MANUFACTURING SECTOR.....	22
4.3 PROMOTING COOPERATION AND INTEGRATION BETWEEN LEADING TECHNOLOGY DEVELOPERS AND CFBC BOILER MANUFACTURERS.....	24
4.4 IMPROVING POLICY FORMULATION, IMPLEMENTATION AND EVALUATION PROCESS.....	24
SECTION 5: CONCLUSION	25
REFERENCES	26
APPENDIX A	27
A1. LIST OF BOILER MANUFACTURERS VISITED.....	27
A2. LIST OF CFBC BOILER TECHNOLOGY DEVELOPMENT INSTITUTIONS INTERVIEWED.....	27
A3. LIST OF GOVERNMENT POLICIES AFFECTING THE DIFFUSION OF CFBC BOILER TECHNOLOGY....	27
APPENDIX B: CFBC BOILER UNITS IN CHINA LARGER THAN 50 MWE	28

SECTION 1: INTRODUCTION

1.1 BACKGROUND OF THE CASE STUDY

As a part of the on-going UNIDO Project US/CPR/96/108 - "Evaluation and Adjustment of China's Sustainable Industrial Planning and Policies", a "Technology output" sub-project has been carried out.

The "Technology output" subproject aims at enhancing the capacity to formulate answers to the following questions:

- What are China's experiences with policies aimed at enhancing the uptake of new technologies, and in particular Environmentally Sound Technology (EST)?
- What are experiences elsewhere with policies aimed at enhancing the uptake of new technologies, and in particular EST?
- What improvements in China's policies for enhancing the uptake of new technologies, and in particular EST, are possible?

During the course of the technology subproject, it was found that too little was known about the actual decision-making in enterprises with regard to technology selection and adoption, and how it is affected by government policies and programs aimed at increasing industrial uptakes of EST. For this purpose, it is proposed that the sub-project will be extended with a case study involving interviews at the enterprise and institute level. This will provide additional and new information that will be very useful for the design of a better-focused, more applicable technology policy.

1.2 RATIONAL FOR SELECTING CFBC TECHNOLOGY AS THE SUBJECT OF THE CASE STUDY

China's fast economic growth since the late 1970s has brought about rapidly increasing energy consumption, in particular the increased coal use. China's coal production peaked at 1.37 billion tons and coal accounted for 74 percent of primary energy consumption in 1996. The acid rain and particulate pollution caused by coal consumption has led to severe negative impacts on human health, air and water quality, agriculture, etc.

Due to abundant reserve and affordable price, coal will remain China's chief energy source in the foreseeable future. Thanks to a number of government policies and programs to tackle the pollution generated from coal burning as well as the ongoing industrial restructuring, the actual consumption of coal has seen declining. In 1999, the coal consumption accounted for 68 percent of the primary energy consumption.

Although more and more coal has been used for power generation, only 38.2 percent of coal was consumed for power generation in China in 1998 while more than 90 percent of coal for power generation in USA (see Table 1).

Table 1 Comparison of key indicators of China and USA coal industry in 1998

Indicator	China	USA
Coal production (Mt)	1250	1014.3
Coal consumption (Mt)	1294.5	942.4
Of which % used for power generation	38.2	90.3
Quality of coal for power generation		
Sulfur content (%)	1.02	1.10 (1996)
Ash content (%)	26.0	9.22 (1966)

Source: State Statistics Bureau of China; US DOE; IEA, Coal Information 1999 Edition

In 1997, per capita power consumption in China was only 101 kWh, far behind 4025 kWh in USA and 1834 kWh in Japan (UN Monthly Bulletin of Statistics, No. 11 2000). Each year, about 20 GW new generation capacity has been added in recent years, of which coal is the dominant fuel. It has clearly demonstrated the importance of advanced coal-fired power generation technologies that convert coal to electricity and heat more efficiently and with less environmental impacts than current prevailing boilers.

At current, most promising coal-based power generation technologies include (ESMAP 2001):

- Supercritical pulverized coal boilers plus flue gas desulfurization;
- Circulated fluidized-bed combustion (CFBC) technology;
- Pressurized fluidized-bed combustion (PFBC) technology;
- Integrated gasification combined cycle (IGCC) system.

There have been 10 supercritical units operating in China now. However, none of them is manufactured by Chinese boiler works. Eight units are made by Russian technology, and the rest two units at the Shidonkou II Plant in Shanghai are 600 MW supercritical boiler and turbine units supplied by ABB (Takahashi M. 2001).

Although China plans to build pilot PFBC and IGCC power plants, PFBC and IGCC have not realized the full commercialization in Europe, the US and Japan yet. Therefore, there will be a long way to go in order to realize and disseminate PFBC and IGCC technologies in China.

Comparatively, CFBC technology (at the capacities of 220 and 410 tons per hour) has been demonstrated by leading international companies such as Foster Wheeler Corporation and Alstom SA in China. Chinese developed CFBC technologies have also been successfully implemented at the 30, 75, 130 and 220 tons per hour. Moreover, domestic boiler manufacturers have launched a variety of technological transfer and cooperation activities with leading foreign CFBC suppliers. Therefore, development and dissemination of CFBC technology provides an excellent case for study on the take-up of EST by Chinese boiler manufactures.

1.3 OBJECTIVES OF THE CASE STUDY

The objectives of the case study are to carry out empirical studies at the selected boiler works that produce CFBC boilers and research institutions that develop CFBC technology on:

- What factors are affecting the decisions of boiler manufacturers in adopting EST, both in their products and production processes (Key to understanding the organizational and structural factors affecting these decisions will be understanding access to information; the establishment, effectiveness, and speed of communication lines; and the current incentives structure.)?
- What factors influence an enterprise decision to buy a more environment-friendly boiler?
- What is the role of policy, government and government officials in influencing enterprises' decisions on manufacturing technologies?
- What is the existing dichotomy between the intended objectives of the selected policies and the actual effects caused by the implementation of the respective policies?
- What policy recommendations can be made, especially drawing from examples of policy instruments found in other countries, to better promote the development and diffusion of EST?

1.4 PROCESS OF THE CASE STUDY

The case study involves the following processes:

Literature review. The first step is to review the relevant literature on China's boiler sector and the environmental technologies in connection with the boiler sector. A series of detailed questions for further exploration will be compiled as the result of the literature review. The team will also focus on previous major research projects on China's boiler sector, such as the World Bank sponsored GEF project - China Efficient Industrial Boilers and China's Agenda 21 Priority Project - Efficiency Improvement and Pollution Control of Medium-small Sized Boilers.

Selection of cases. The team has contacted relevant R&D institutes and relevant government agencies to decide potential boiler manufacturers to be studied in May and June 2000. The selection criteria used involve the size of the companies, ownership structure, geographic balance, and last but not the least willingness to cooperate in this study. After the initial selection of the target boiler manufacturers, the team will collect as much information about the companies in general and their products in specific. A large amount of relevant information can be obtained via the Internet. Professional journals in Chinese will be another important source of information.

Interviews. On the bases of the above-described literature review, the research team will carry out interviews to policy-makers at the central and provincial levels, management of selected boiler manufacturers, researchers of related R&D institutes and decision-makers of the end-users of industrial boilers. The interviewees at the

company level should involve, to the extent possible, Managing Director, Technology/Production Manager (or Chief Engineer), and Sales Manager.

Report writing. A report on the case study is prepared to summarize the findings of the interviews. It is the authors' hope that some of the findings would be fed back into the policy development and implementation process.

1.5 STRUCTURE OF THE REMAINING PAPER

The remaining part of the paper is structured as follows. Section 2 introduces the development of CFBC technology worldwide and in China. Section 3 summarizes the findings from interviews at the boiler manufacturers and CFBC technology research institutes and universities. Section 4 provides policy recommendations arising from the case study. Section 5 concludes the paper.

SECTION 2: OVERVIEW OF CFBC BOILER TECHNOLOGY DEVELOPMENT WORLDWIDE AND IN CHINA

2.1 REVIEW OF CFBC TECHNOLOGY DEVELOPMENT WORLDWIDE

Circulating fluidized-bed boiler (CFB) technology was first developed in Finland, Germany and the USA in 1970s. The first commercial size boiler with circulating fluidized bed (CFB) combustion started up in Finland in 1979. Since then, CFB technology has received a wide acceptance in many industrial applications, for example, for use in burning fuels that contains a high moisture content. CFB technology offers many advantages, including: fuel flexibility; superior emissions performance; good applicability for low-grade and hard-to-burn fuels and application for newer energy concepts; high suitability for repowering; and CFB by-products are non-hazardous and can be reused.

CFB boilers gained acceptance for power generation during the early 1980s, mainly in cogeneration applications. One driving force for the development work was the dramatic increase in oil price during the oil crises of that time. The primary advantage of CFB technology is that it enables the substitution of expensive fuels with cheaper solid fuels. Circulating fluidized bed (CFB) technology has developed from being largely confined to industrial applications to utility scale applications.

Since the late 1980s, the coal-fired power generation equipment manufacturers have gone through a fundamental consolidation through mergers and acquisitions (M&A). With the rapidly changing market for electricity as well as ever-increasing competitions caused by restructuring and deregulation of the power sector, international power generation business leaders have to react quickly to the trends. This is the primary driving force for the wave of M&A activities, which aim at improving efficiency and productivity and economies of scale, implementing global market strategies, and maintaining a technology cutting edge.

This following M&A activities among the power generation industry has far-reaching implication for the worldwide CFBC technology landscape.

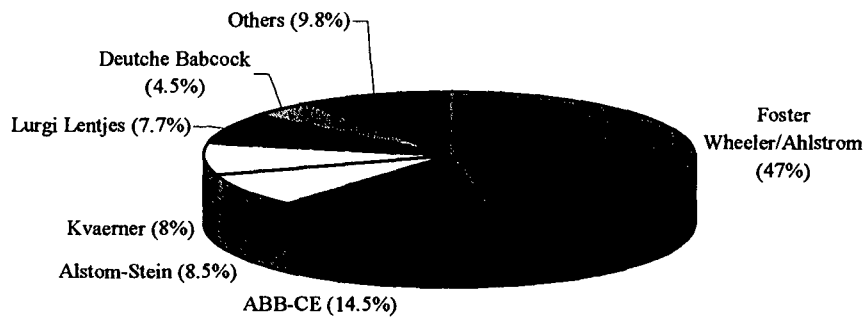
- The wave started with Sweden-based Asea's merger with Brown Boveri of Switzerland in 1987, which gave birth to ABB Asea Brown Boveri Ltd., the world's largest manufacturer of power generation equipment.
- In November 1989, ABB acquired the US-based Combustion Engineering Inc. and formed ABB-CE to develop and market the power generation (including CFBC technology) and industrial automation business worldwide. CE was the global leading boilermaker.
- In June 1995, Foster Wheeler Corporation (FWC) acquired Ahlstrom Pyropower Inc., a division of A. Ahlstrom Corporation, a privately held Finland-headquartered global paper and engineering group. Ahlstrom Pyropower, based in San Diego, California, is a recognized leader in the global supply and manufacture of fluidized bed combustion (CFB) systems to utility and industrial customers and also provides a full range of boiler services, and plant operations and maintenance services. Ahlstrom

Pyropower's operations were conducted in the U.S., Europe and Asia. Ahlstrom Pyropower has CFB units in operation throughout the world. The increased market access, the technological leadership, and operating synergy resulting from the acquisition of Ahlstrom Pyropower strengthened Foster Wheeler's global leadership position and long-term growth in fluid bed technology.

- Germany-based ETV obtained a CFBC technology license from Ahlstrom Pyropower in the period 1983-1992. In 1992, the license expired, but because it covered an early design, ETV apparently was able to continue to market its CFBC technology independently. Later, ETV was acquired by the Alstom Group. The Alstom Group also includes Stein Industry, which was a Lurgi CFBC technology licensee.
- In March 1999, ABB and Alstom announced the merger of their power generation businesses in a 50-50 joint company, to be called ABB Alstom Power. This means that ABB Alstom Power integrated the CFBC technologies from ABB-CE and Alstom-Stein.
- ABB Alstom Power had not lasted for long. In April 2000, Alstom SA acquired ABB Ltd.'s 50% share of their power-generation joint venture - ABB Alstom Power. This implies Alstom SA acquired all the CFBC technologies from ABB Alstom.

After the above-listed major M&A activities, Foster Wheeler Corporation and Alstom SA become two world leaders in CFBC technology development. As of 1999, there are about 300 atmospheric CFB units in operation or under construction. Commercial units up to 400 MWe are being offered. As shown in Figure 1, the worldwide CFB technology has been primarily controlled by a few companies in developed countries.

Market share of CFB technology worldwide



Source: David Pai and Folke Engstrom, Foster Wheeler, Livingston, USA. Fluidized Bed Combustion Technology - the past, present and future. Modern Power Systems. (21) November 1999, P22-26

2.2 REVIEW OF CURRENT STATUS OF CFBC TECHNOLOGY DEVELOPEMNT IN CHINA

China has the second largest power generation capacity in the world. A very large proportion of this is based on thermal power plants, with pulverized-fuel boilers. The thermal efficiency of these plants is relatively low (and emission of pollutants is high). Improvement in the thermal efficiency and environmental performance of these plants is an important objective of the Chinese government. Clean coal technologies, including CFBC, can play an important role in achieving this objective.

Pulverized fuel based power plants emit high levels of pollutants, such as SO₂, CO₂ and NO_x. The need to reduce these emissions has led to the development of a number of alternative technologies. These include:

- End of pipe solutions: including flue gas desulphurization for SO₂, selective reduction for NO_x and “bag houses” for particulate matters.
- Advanced combustion technologies including bubbling bed fluidized boilers, circulating fluidized bed combustion boilers (CFBC), pressurized fluidized combustion bed boiler (PFBC) and integrated gas combined cycle (IGCC).

CFBC boilers, with which this case study is mainly concerned, produce very little SO₂ and NO_x. They are particularly suitable combustion of poor quality coal with high sulfur content.

China started the research and development work of fluidized-bed combustion (FBC) technology, primarily bubbling fluidized bed combustion boilers in the early 1960s. More than 3,000 bubbling FBC boilers are being operated throughout China and all of them were designed and manufactured in China. At current, China ranks first in the world in terms of the number of small-scale FBC boilers.

The principal driving force for this development is to make use of various low quality fuels rather than for environmental consideration.

The development of the circulated fluidized-bed combustion (CFBC) technology was first supported by the 7th Five-Year Program for National Key Science and Technology Development. In 1988, the Institute of Engineering Thermophysics (IET), in cooperation with the Jinan Boiler Works (JBW), made breakthrough progress in research and development of the first CFBC boiler with live steam output of 35 tph. The first 35 tph CFBC boiler was manufactured by JBW and installed and put into full operation at the Jinan Mingshui Thermal Power Plant. This stands for a milestone of CFBC technology development in China. In 1991, the first 75 tph CFBC boiler was put into operation in Jingxi Thermal Power Plant, which was also designed by IET and manufactured by JBW.

With technical assistance form the United Nations Development Programme (UNDP), two 220 tph CFBC boilers were imported from Ahlstrom Pyropower. The Harbin Boiler Works was subcontracted to supply steam drums, boiler membrane walls, convective heat transfer assemblies and steel structure framework. The two 220 tph CBFC boilers were put into operation in November 1995 and February 1996 respectively. Meanwhile under the support of this technical assistance project, a 1.5

MWe CFBC pilot plant and a few cold model test rigs were installed at the CFBC R&D Center of IET.

China already has the largest number of CFBC boilers in the world. Most of these boilers are based on locally developed technologies. While their cost is low, their environmental performance is poor. Also, the locally developed technologies are suitable for designing only small boilers. The boilers produced by the world's leading manufacturers, on the other hand, are larger and produce very few emissions.

In the 1980s, when import of CFBC boilers was not permitted, boilers based on local technology had a large market. The situation changed in the 1990s when import of these boilers was permitted. The Chinese firms were unable to compete with the imported boilers, and entered into collaboration with foreign firms for import of technology. At present at least five Chinese firms produce CFBC boilers under foreign collaboration.

At present, 130 t/h CFB boilers have been fully commercialized in China. The Department of Thermal Engineering at Tsinghua University and the Institute of Engineering Thermophysics (IET) of the Chinese Academy of Sciences are among the leading domestic technology developers.

Tsinghua University has to date signed contracts to sell more than 10 CFB boilers (220 t/h). The first 220t/h CFB boiler designed by Tsinghua University and manufactured by the Wuxi Boiler Works is scheduled to be put into operation in late 2001.

As part of the 9th Five-Year Plan for National Key Science and Technology Program, the Ministry of Science and Technology funded the R&D and entire engineering design of the 420 t/h CFB boiler (matching the 125 MW power plant). The R&D work was led by Tsinghua University in co-operation with the Xi'an Thermo-engineering Design Institute and Zhejiang University. The engineering design was led by the Harbin Boiler Works in co-operation with the Dongfong Boiler Works.

The mainstream perspective of Chinese research community towards the development of CFB boiler technology is to speed up the development of the manufacture technology for the 410 tph CFB boiler with indigenous intellectual property rights. The rationale for this viewpoint is threefold:

- The market demand for 410 t/h (equivalent to 100 MW coal-fired power plants) or above CFB boilers is enormous. This is primarily due to the soaring market caused by the more stringent policies and regulations, and the low product price as compared to foreign imported CFB boilers.
- The development of 410 t/h CFB boilers will help build up China's capacity for assimilating the large-scale advanced boiler technologies to be imported from foreign countries.
- The development of 410 t/h CFB boilers will also enhance China's technological capacity for developing other Clean Coal Technologies (CCT), such as pressurized circulating fluidized bed combustion boilers (PFBC) and integrated gasification combined circle boilers (IGCC).

The primary driving forces for development of CFB boilers are to expand the suitability of a wide range of fuels and stable combustion status. In recent years, increasingly high environmental requirements in terms of SO_x and NO_x emissions have substantially promoted the expansion of market demands for CFB boilers.

China is planning to build a 300 MW CFBC demonstration plant at Baima Power Plant in Sichuan Province. The intent of the SDPC and State Power Corporation, which is the leading ministry and company respectively for this initiative, is to solicit bids for design and technology transfer of 300 MW CFBC boiler. The technology is intended to be shared with the three main Chinese boiler makers - Shanghai, Dongfong and Harbin - although the CFBC boiler would be probably be built by Dongfong Boiler Company due to its closer proximity to the Baima Power Plant. At the early stage of project negotiation, the State Power Corporation negotiated with Foster Wheeler Corporation, ABB-CE, and Alstom-Stein. However the recent M&A between ABB and Alstom has reduced the competition to just two firms, FWC and Alstom SA.

SECTION 3: FINDINGS OF INTERVIEWS

3.1 FINDINGS FROM INTERVIEWS WITH CHINA'S CFBC BOILER MANUFACTURERS

Government energy and environmental policies started to affect industrial decisions on technology selection and implementation. However, there are some problems to be solved for these policies and regulations to play their full role.

The efforts to alleviate the power shortage in the 1980s and early 1990s led to inefficient small coal-fired power plants proliferating all over the country. The environmental impact of small thermal power plants and inefficient boilers in China is extremely severe and well recognized. In May 1999, the State Council approved a policy entitled "Suggestion for Implementation of Retirement of Small Thermal Power Plants" that was proposed by the State Economic and Trade Commission (SETC). The policy required all small power plants below 50 MW to retire or shut down their operation by the end of 2003. Only cogeneration and low heating value[□] burning units with capacity less than 50 MW can be excluded from this retirement scheme. The policy particularly stipulated that all low heating value fuel burning power plants must adopt CFBC technology.

The policy has been the single most effective energy and environmental one affecting China's electric power sector so far. All the boiler manufacturers interviewed during the case study voiced the effective implication of this policy for expanding the market demands for CFBC boilers to retrofit the small thermal power plants that shall otherwise be shut down by the end of 2003.

It is interesting to see that the proportions of CFBC boilers in the overall production of all the interviewed enterprises have gone up. For example, more than 50 percent of Jinan Boiler Works' products in the last two years are CFBC boilers. Sichuan Boiler Works has been kept busy producing CFBC boilers for retrofitting the coal-fired power plants with the capacity of less than 50 MWe.

However, the primary deficiency associated with this policy is that no effective monitoring and enforcement mechanisms are existent to make sure those CFBC boilers burning low grade fuels are actually injecting limestone for the purpose of in-process desulfurization. Boiler manufacturers all mentioned that most CFBC boilers are not operating the limestone injection operation in order to reduce operating costs. Without limestone injection, these small power plants burning low grade fuels can be the worst pollutant sources in China. Much of the higher capital costs for installing CFBC boilers are simply wasted due to the skip of the desulfurization function in those CFBC boilers.

(1) [□] Low heating value fuels have a heating value less than 12,550 Kj/kg and include fuels such as coal wastes, peat, oil shale, municipal solid wastes, biomass, coal-bed methane gas, and blast furnace gas.

All boiler manufacturers interviewed concurred that the boiler buyers decide the environmental features of the boilers to be purchased. Over the recent years, more and more buyers tend to incorporate the emission requirements in the bidding documents. However, the actual implementation of environmental regulation remains problematic. In most cases, boiler manufacturers only conduct a 24 hour test operation of the limestone injection system and after that most of them will stay unused unless the monitoring and inspection by local environmental authorities. Leading boiler works all hope enforcement of environmental regulation would be reinforced and this will undoubtedly enhance their interest in development and uptake of EST.

Chinese boiler manufacturers lack in-plant R&D capability and primarily rely on external sources of CFBC technologies.

In China, boiler manufacturers generally do not take the responsibility for carrying out major R&D activities related to boiler technologies. On the contrast, specialized research institutes and universities are still the primary actors in boiler technology development. In-plant R&D capacity of Chinese boiler manufacturers is commonly weak. The in-plant R&D capability primarily confines to the design, engineering and quality management of boiler manufacturing. The principal sources of boiler technology are from external entities, including technological cooperation with domestic research institutes and universities, joint ventures or wholly foreign own subsidiaries, and technology licensing from leading international boiler manufacturers.

More specifically, the primary sources of CFBC technology for China's boiler manufacturers are threefold:

- Licensing of advanced foreign boiler technologies. For example, Dongfong Boiler Works, Ltd. licensed 50-100 MWe CBFC technologies from the FW. It is a relatively quick approach to access the advanced CFBC technology. However, the technology license fee is usually prohibitively high and usually this technology transfer arrangement is one-off activity and Chinese counterparts cannot access related latest technology development and have to keep buying new technology.
- Forming joint ventures or establishing wholly foreign owned subsidiaries. For example, Beijing Boiler Works formed a JV with US-based B&W. As a result, BWBC obtained some advanced CFBC boiler technology from B&W. However, when the JV or subsidiary is fully treated as a cheap production basis, it will be difficult to develop R&D capacity at the JV or subsidiary.
- Acquisition of smaller scale CFBC technology from domestic universities and research institutes. There are two major means of this collaboration. The first type is that boiler works approach R&D institutes for acquiring specific technical supports. After a boiler works signs a contract, the boiler works may have to approach one or more R&D institutes for specific technical supports if it cannot resolve all technical problems by itself. In some cases, boiler works also seek the technology transfer from the R&D institutes, which have implemented successful projects. The second type is that

universities and research institutes approach the boiler manufacturers to carry out the pilot projects of their R&D results.

Some of the firms interviewed have been engaged in the development of CFBC boiler technology in the past. These efforts were carried out both independently and in collaboration with universities and research institutes. However, the locally developed technology is suitable only for small CFBC boilers, so none of the firms have been able to produce large CFBC boilers. Many initiatives have therefore been abandoned or reduced in scale. Most of the firms report that their R&D and technological activities are mainly concerned with solving production related problems.

Despite the enhancing capacity of enterprise R&D capacity, all boiler manufacturers rely on external sources of technology. In another word, they are still unable to develop systematic boiler technology on their own. Three leading boiler works are working on CFBC boilers from 240 tph till 440 tph. Until now, they have primarily relied on licensing of foreign technologies. It is interesting to see that with the support and encouragement of government, there have been more cases in technological cooperation on the scaling-up of CFBC boilers between leading boiler works and key CFBC technology development institutes. In particular, the Ministry of Science and Technology (MOST) have effectively nurtured the demonstration of 125 MWe reheat CFBC boiler during the 10th Five-Year Program for S&T Development (2001-2005).

Policy barriers remain bottlenecking the further growth of the market for CFBC boilers in China

The case studies suggest that the government's environmental policies are beginning to have some effect on the choice of technology. In the past, most customers looking for CFBC boilers were mainly concerned with the problems related to the use of poor quality coal; the problem of emissions was not given much emphasis. There are indications that this is changing and some customers are beginning to ask for boilers with low emissions. The demand for CFBC boilers has also been affected by the government's policy of retiring small, polluting boilers. This has motivated some of the users to replace their old boilers with CFBC boilers. However, it must be stressed that, in spite, of these favorable trends, the demand for CFBC boilers is still very small.

According to the firms, the following factors are responsible for the small demand for CFBC boilers:

- The environmental emissions standards for the coal-fired power plants built before 1992 are not very demanding. In many instances they can be met with the addition of end-of-pipe equipment. This is a less costly option than the use of CFBC boilers.
- The implementation of the standards is lax. For instance, in order to minimize operational costs, a number of boiler producers have reported that in many instances utilities which have installed CFBC do not inject lime (required for the control of SO₂) except when they are being monitored. If the

monitoring of standards was stricter, the polluting firms would be forced to install and use clean coal technologies, including CFBC boilers. At present, the local environmental protection authorities lack the necessary equipment to carry out continuous online monitoring of emissions.

- Although, in some cases, the environmental standards for newly built coal-fired power plants are more stringent than other countries, the utilities lack the resources to install CFBC boilers. As the cost of CFBC boilers is higher than conventional alternatives, they are used only when other options are not available. □

Leading international companies still dominate the large-scale CFBC boiler (with capacity 220 tph or above) market in China but Chinese domestically development CFBC technologies have become more competitive for small CFBC (130 tph and below) boiler market.

Appendix 2 summarizes the most CFBC boilers larger than 50 MWe that have been put into operation or under construction in China. Obviously, international vendors, particularly Foster Wheeler Corporation, have been dominating the CFBC market in China with capacity of 220 tph or above. By means of licensing of foreign CFBC technologies, Dongfong Boiler Works, Ltd. and Harbin Boiler Works, Ltd. With the further development and improvement of Chinese CFBC technologies, Chinese manufacturers will dominate the CFBC boiler market with capacity of smaller than 130 tph.

Even the CFBC boilers produced by Chinese boiler works under the license of foreign technology have a very high price due to the high technology access fee and loyalty posed by the foreign licensors. For instance, Harbin used to have a arrangement with Ahstrom Pyropower Inc. for the development and supply of CFB boilers up to 50 MWe. For every unit of 50 MWe CFB boiler produced under this arrangement, HBC had to pay \$2.2 million for technology licensing fee (Ma Chi, Shi Han. 2001). Plus the purchase of the key equipment and components, the price almost doubles the price of Chinese domestic CFBC technology.

Because of the much higher price of 220 tph CFB boilers produced under the foreign technology license, the latest order of 220 tph CFBC boilers to be produced by Chinese technology has approached 20 units. This means domestic CFBC technology will be very competitive for the CFBC boilers with capacity up to 220 tph.

Box 1: CFBC Technology Development at Babcock & Wilcox Beijing Company Ltd.

(2) □ For example, Austrian Energy has installed 4 CFBC boilers at two paper mills in Suzhou industrial park in the Jiangshu province for providing steam for two 100 MW power plants and the paper production at the mills. Studies of their performance shows that the capital cost of these boilers is higher than those of conventional boilers. However, once strict regulations regarding the emission of SO₂ are implemented, and the cost of desulfurization plant is added, these plants will be cheaper. See: Katzenberger Helmut and Ingo Tschanum, "Implementation of Circular Fluidized Boiler in China", at http://www.nemesis.at/publication/gpi_98_2/articles/45.html. Also, see: Jin and Liu (1999), op.cit

In 1986, the US based Babcock & Wilcox and Beijing Boiler Works established a 50-50 joint venture Babcock & Wilcox Beijing Company Ltd. (BWBC). In the same year, Beijing Boiler Works reached into agreement with Harbin Institute of Technology (HIT) to produce CFBC boilers.

On the basis of the CFBC technology of Harbin Institute of Technology, BWBC produced the first 35 tph CFBC boiler for a sugar mill in Inner Mongolia. Between 1990 and 1993, BWBC had altogether sold 15 CFBC boilers with varying capacities from 35, 50 to 75 tph.

1993, the BWBC decided to end its cooperation with Harbin and adopt the more advanced CFBC technology developed by B&W. However, BWBC had not succeeded in selling any single CFBC boiler in China during the period 1993 and 1998 due to the prohibiting high price.

In 1999, BWBC resumed its technological cooperation with Harbin Institute of Technology to produce low cost CFBC boilers to satisfy the emerging market demands. By combining the B&W technological advantage and HIT's low cost feature, BWBC has signed 6 contracts on CFBC boilers since 1999.

Source: interview with BWBC executives in July 2000

Irrational industrial structure and over-heated market competition have undermine the profitability and in turn technology innovation capacity of Chinese boiler manufacturers. However, some Chinese boiler manufacturers started to react to this challenge by enhancing their in-plant technological capacity via internal organizational transformation and correcting incentive.

In contrast to the enormous M&A activities among international power generation companies, China's boiler manufacturing sub-sector has remained unusually stable. Due to rapidly growing market demand for industrial boilers in the 1980s, the number of boiler producers in China soared. There are currently more than 2000 boiler producers with a range of capacities. Among them, 706 enterprises hold boiler manufacturing permits (Classes A, B, C, D, E1 and E2). In 1993, the grand sales volume of industrial boilers (Class D and above) reached its peak at 28,900 units and with a total capacity of some 99,700 tph, and since then, actual sales of industrial boilers have been declining. The combination of steady growth in the boiler manufacture capacity and decrease in market demand has created fierce market competition. The market price of industrial boilers has maintained stagnant or declined in since the mid-1990s, despite inflation, and as a result the profit margins of coal-fired industrial boilers have become extremely thin. The State's decision to halt the construction of additional coal-fired power plants during 1998-2000 further worsened the problem. Because of the deeply rooted local protectionism and recent concern about the unemployment, it is difficult to get the low-end boiler producers out of the market competition. Because of this unusually low profit margin, many of the boiler works interviewed confirmed their inability to invest in technological innovation.

For instance, Harbin Boiler Works only spends about 0.2 percent of its sales on R&D (excluding the salary of R&D personnel), far less than that of the international average level in the large utility boiler industry (Jin Y., Liu X. 1999)

Market competition has become even more vigorous since the power sector reform in 1998. Because of lack of market demands for large-scale utility boilers, the leading boiler works also eagerly join the competition of smaller utility boiler, particularly the CFBC boiler manufacture in the past years. The cascade effects affect the boiler manufacture sector considerably and pose remarkable pressures on the smaller boiler works, including the Sichuan Boiler Works and other second group boiler works. To survive, those boiler works have had to expedite their reform processes. The interviews at the firm level have revealed the following trends:

- More stress has been given to technology development recently. Sichuan Boiler Works, HBW and SBW recently increased the salary of the technicians and engineers.
- All the enterprises visited expressed their new plans for technology acquisition from either foreign sources or domestic institutions.
- Many younger technicians have been promoted to the middle level management positions.
- The linkage and communications between the marketing division and technology development division have been enhanced.

Over the recent years, the fierce competition in the boiler market has placed higher technical requirements, e.g., higher reliability, lower price, even emerging environmental performance, on Chinese boiler works. This has driven many boiler works to recognize the growing importance of the in-plant technical expertise towards their market competitiveness. Many interviewed boiler works have substantially increased the salary and other welfare of their technical and management staff to motivate the technological innovation at companies. Another interesting phenomenon is that many young technical staff have been quickly promoted to middle and senior management level. Interestingly, the growing importance and welfare on technical staff and the increasing competitiveness were mutually supportive.

Domestic boiler manufacturers lack access to government policies, financial support and technical information that they used to enjoy. Meanwhile, government has not provided alternative support measures in line with the market economic system such as tax exemption for technological innovation.

In the past government policies and programs were the primary driver for developing, transferring and adopting more advanced technologies that are, in many cases, environmentally sounder. The government also provided the funding for doing this. Under this arrangement government agencies played the leading technology assessment and selection role while boiler works were more responsive and not that much concerned about the actual results of the technology upgrading activities.

The situation has seen a fundamental change due to the transition to a market-oriented economy and reduction in direct government financial investment.

Nowadays, boiler works mostly follow the market signals to decide their technological selection. A few boiler works are forward looking by even forecasting the future impacts of government policies on the boiler market. Boiler works become indirectly affected by relevant government policies via market signals.

In general, boiler works either invest substantially or face difficulty in accessing the government policies and other information in a comprehensive and timing manner. The channels of information dissemination are fragmented and fixed. Some companies mentioned that most effective means of access government information are private relationships. This means that they may not only access the policies on paper but also the insights and other relevant information of policies and programs.

3.2 FINDINGS FROM INTERVIEWS WITH CHINA'S CFBC TECHNOLOGY DEVELOPERS

Leading CFBC technology R&D capabilities reside in universities, Chinese Academy of Sciences, and research institutes affiliated with the State Power Corporation. None of them is affiliated with any boiler manufacturers. In many ways, the limited R&D resources are fragmented and lack of coordination and cooperation among them.

The Department of Thermal Engineering of Tsinghua University, Institute of Engineering Thermophysics (IET) of Chinese Academy of Sciences, and the Thermal Power Research Institute of the State Power Corporation are the three leading CFBC technology developers in China. So far, none of the boiler manufacturers owns a CFBC technology center.

However, all of these leading institutes have less than 30 researchers working on CFBC and a variety of boiler-related research activities. To compete for very limited government funding in this field, all the three

Domestic universities and research institutes have been driven downstream along the technology innovation chain. They assume more CFBC technology dissemination role rather than concentrated on basic theoretic research to underpin the development of CFBC technology.

Because of the prevailing lack of R&D capacities in Chinese boiler works, research institutes have to even produce complete technical design blueprints and even comprehensive construction specifications. For instance, Department of Thermo-energy Engineering of Harbin Institute of Technology have had to supply their collaborative boiler manufacturers with comprehensive technical design blueprints for all 20 CFB boilers and even detailed installation specifications for 5 boilers. However, B&W Beijing Company, a joint venture with US-based W&B, has been able to make the detailed technical and construction designs on the basis of the general technical designs that are provided by Harbin Institute of Technology. The prevailing and sober trend of the downstream extension of the R&D activities at Chinese research institutes reflects actual weak capacity of technological innovation at the enterprise level and severe wastage of precious, limited R&D resources in

uncritical R&D activities. It indicates the deficiency of China's technological innovation system.

The technological cooperation between boiler manufacturers and R&D institutes are mainly driven by the needs of boiler end-users. Industrial end-users most likely approach boiler plants for new type of boilers. If the boiler works cannot satisfy the particular technical requirements, it will turn to specialized boiler R&D institutes for technical backstopping.

Domestic R&D on CFBC technology has been substantially under-funded as compared to the monies spent on licensing of foreign CFBC technologies. In particular, domestic developed technologies lack means of commercialization through demonstration projects.

Although it has failed to develop state-of-the-art CFBC technology, China has built strong capabilities in this area. It is important that these capabilities are sustained, as they are vitally important for the absorption of imported CFBC technology, and indigenization of production. Additionally, such capabilities are needed to improve the locally developed technology to produce small CFBC boilers. It is therefore important that government policies are directed at strengthening the existing capabilities. The existing technology policies have some important weaknesses, which diminish their effectiveness. Firstly, governmental support appears to be largely focused on the development of new technologies, and does not give sufficient priority to the absorption and adaptation of imported technologies. Secondly, the support is provided largely to research institutes and universities, and not to industrial firms. Thirdly, government support is distributed too thinly among a large number of research institutes and universities.[□] As a result, none of the centers receives enough support to develop, demonstrate and commercialize state-of-the-art CFBC technology.

At current, the synergy between different government programs has been little. The link between CFB technology R&D activities and technology importation remains missing.

A range of government agencies influences the development and diffusion of EST for the coal-fired boilers. The Ministry of Science and Technology (MOST) takes responsibility for funding the development and demonstration of clean coal technologies, including CFB combustion technology. The State development Planning Commission (SDPC) takes the lead in importing and commercializing large-scale CFB boiler technology, which will match a 300 MW power generating unit in the case of Sichuan Baima Power Plant. Meanwhile, SDPC also coordinates the Japanese Green Aid Program, which has supported four pilot CFB boiler projects to demonstrate the Japanese technologies. The State Economic and Trade Commission (SETC) plays the leading role in diffusing energy efficient and environmentally sound technology such as the CFB boiler by retrofitting old coal-

(1) □ Compared to developed countries, there is a large number of research centres and firms engaged in research and production of CFBC boilers.

fired power plants and existing industrial boilers. SEPA regulates the environmental emissions from coal-fired power plants and industrial boilers that ultimately affect the decision of industrial facilities on whether or not to abate their pollutant emissions. The State Administration of Quality, Technical Supervision and Quarantine formulates and oversees the technological and safety standards of boilers at large.

Many government programs exist to support the development and adoption of clean coal technologies. On the one hand, most government programs are suffering from insufficient financial resources with regard to the development and diffusion of EST for the boiler sector. On the other hand, non-concerted and redundant government initiatives have proven to be ineffective in accomplishing the original goals and have even turned out to be a waste of resources.

As described earlier, the leading institutions in the field of CFBC technology are universities and research institutes affiliated with CAS. Since the early 1990's, MOST started to foster the consortium between research institutes and enterprises to bid for the National Key Science and Technology Program. An interesting experiment is the Study on Core technology and Master Design of 125 MWe CFBC Boiler with Reheat Process during the period of 1996 and 2000. MOST particularly requires that research institutes and boiler manufacturers have to twin to compete for the demonstration project. At this stage, Tsinghua has twined with HBC; IET has tied with SBWL; and Xi'an Thermal Power Research Institute tied with DBC to bid for the demonstration project.

Some literatures have discussed about the problem with lack of funding for assimilation of imported technologies that prevents China from better tapping the advanced technologies. On the contrary, South Korea has done a much better job in this regard. The case study argues that the problematic efficiency of technology importation in China has been not only caused by insufficient funding for technology assimilation activities as compared to the funding for technology importation. On the one hand, research institutes carry out bulk of the technology development activities but only play a marginal role in technology importation. The enterprises that take leading responsibility for assessment, selection and implementation of technology import but still lack in-plant technical capability.

Until the early 1990s, the state organized and coordinated the technology importation activities. Government paid the full costs associated with technology importation. At that time, government usually involved both enterprises that installed and operated the imported technology and equipment and related research institutes that provided technical advice and carried out some technology adaptation and assimilation activities. Under that arrangement, some cooperation and communication took place between technology development institutes and technology implementing institutions, i.e., industrial enterprises. However, government substantially reduced the direct grant support to enterprises for importing foreign advanced technology and equipment, if any remained, after the 1990s. The enterprises themselves have to pay for the technology importation if they

decided to do so². However, it is up to the respective enterprises to decide whether or whom to involve in their technology importation process. For obvious reasons, the enterprises become much more reluctant to involve the external research institutes in their technology assimilation process.

The missing link between research institutes and enterprises also constitutes a significant barrier towards the effective assimilation of imported foreign technologies, thus undermining the overall efficiency of China's technology importation strategy.

Emerging means of strategic technology alliance between domestic boiler manufacturers and research institutes/universities

It is important to pointing out that new means of technological cooperation are emerging over the recent years. One example is that IET/CAS and SBW are seeking to form a more strategic technology partnership. The author is bold to predict that at some point SBWL will consider acquiring the CFBC technology division from IET or turning it into a joint R&D center between SBW and IET. Another example is that Zhejiang University has been formed a joint venture with a private company Jingjiang Group to commercialize its waste-to-energy boiler technology. Compared to the prevailing technology cooperation mode, which is characterized by its ad hoc, unstable, and in turn high in transaction costs, these new modes might be more effective for long-term cooperation.

Government should encourage these as well as technology collaboration between Chinese research institutes/enterprises and international leading boiler manufacturers.

Box 2: CFBC Technology Cooperation between Shanghai Boiler Works, Ltd., Institute of Engineering Thermophysics, and Mitsui Engineering & Shipbuilding Co., Ltd.

Shanghai Boiler Works, Ltd. (SBWL) has gone through the transition from technology procurement to technology co-operation. Since 1999, SBWL, Institute of Engineering Thermophysics (IET) of the Chinese Academy of Sciences (CAS) and the Mitsui Engineering & Shipbuilding Co., Ltd. (MES), Japan launched collaborative development and demonstration of CFBC boiler technology. The three partners agreed to share the R&D results. All three partners have final disposal and publicity rights towards the technology property. All the successful implementation of the CFB boiler technology will be treated as the success stories of any of the three partners. Both MES and IET will provide technical supports to SBWL in its bidding for Chinese projects.

MES has developed and implemented CFB technology in Japan. The obvious disadvantage associated with its sophisticated CFB technology is its high costs. The motivation of MES is to simplify its complicated CFB technology and substantially

(2) ² The technology importation must be reviewed and approved by the government even if the enterprises would pay by themselves.

reduce its cost. Due to the difficulty to demonstrate the simplified CFB technology back in Japan, MES hopes to successfully demonstrate the simplified CFB boiler technology in China and then implement it in Japan and anywhere else.

The IET has been very successful in cooperating with many Chinese boiler manufacturers. The IET would like to enhance its leading theoretical research position in the CFBC boiler technology. However, IET is weak in engineering design and manufacturing. The main drivers of IET are to work with the Chinese leading boiler manufacturer, SBWL and the international leading boiler manufacturer, MES.

SBWL has built up a strong design and machining capacity. From this technological collaboration, SBWL serves as the design and manufacture base while receiving technical supports and enhancing its credibility. SBWL has benefited from the technical co-operation with MES as described in the following case.

Japanese Electric Power Development Company (EPDC) is a unique wholesale electric utility in support of development and demonstration of new power generation technologies on behalf of the Japanese government. In order to demonstrate the CFB technology special for high sulphur and ash content coal, EPDC planned to participate in the construction of 130 tph CFB boiler technology in the Shangdong Lingshi Power Plant by forming a joint venture with Chinese partner. SBWL wanted to supply the CFBC boiler for the pilot project, however this technology has not been demonstrated in its full capacity.

EPDC first required that certain guarantee of commercial risk associated with the CFBC technology should be provided before the joint venture agreement would be signed. After further negotiation, MES agreed to present a technology evaluation report on the CFB boiler that is being designed by IET and manufactured by the SBWL. At present, the project has been initiated.

Source: Interview with SBWL in August 2000

SECTION 4: POLICY RECOMMENDATIONS

4.1 BETTER COORDINATION AND SYNERGY BETWEEN GOVERNMENT AGENCIES

Better coordination and synergy between government agencies, particularly the SDPC, SETC, MOST and SEPA, will be crucial to maximize the effects of government policies and programs with regard to China's CFBC technology development. Many opportunities to maximize the limited sectoral initiatives would be seized if interagency coordination and cooperation could be enhanced. An interesting example is the successful collaboration between MOST and SEPA in the Clean Energy Programme in 1999, which prioritizes the adoption of advanced industrial boilers as a key technical solution for the Urban Clean Air Project. Therefore, it is vitally important to establish a mechanism for co-ordination between government agencies and boiler industry associations, in order to enhance communication and cooperation for development and diffusion EST for the boiler industry. Any such interagency co-ordination mechanism should consider the following matters as a priority:

1. Closer linkage between the absorption and adaptation of imported advanced technology, and the fostering of development of indigenous technology. Specifically:
 - Better co-ordination and consistency between the government technology import programme and domestic R&D programme;
 - Participation of a few leading R&D institutes in both absorption and adaptation of imported technologies, and indigenous technology development and demonstration;
 - Fostering of co-operation between key domestic R&D institutes and multinational corporations for technology development and diffusion.
2. Better integration and enhanced enforcement of technical, quality and environmental emissions standards, between SEPA and the State Administration of Quality, Technical Supervision, and Quarantine.
3. Concerted efforts in the demonstration and commercialization of domestically developed CFB technology between SDPC, MOST and SETC.

It is suggested that government would provide objective, timely information and opener access to government policy and regulation formulation process to China's boiler manufacturers, especially those smaller boiler works.

Government should give more support to the development of technical and quality standards and the dissemination of information and knowledge. Except for the largest boiler producers such as the Shanghai Boiler Works, Ltd., many smaller boiler manufacturers including Sichuan Boiler Works expressed their needs for better access to information and more participation in the formulation process for policies and standards. The Hangzhou Boiler Works explicitly asked for direct government intervention with the potential redundant importation of "waste-to-energy" (incineration) boiler technology by different Chinese boiler producers. Since enterprises now make their own decisions on technology options, including technology transfer from foreign companies by using their own funds, it is

inappropriate for the government to make too much direct intervention on the enterprise's internal operation. However, it is very important that government either itself carries out, or entrusts neutral technical institutes, to conduct comprehensive technology assessment and market surveys. The findings of the technology and market study will assist Chinese boiler producers, in particular smaller ones, to make more informed and rational decisions on their technology and business strategy. In the long run, the boiler industry associations should play a much more active role in bridging the gap between government and boiler producers. In view of the current weak status of the industrial associations, it is better for the government to support the capacity and credibility development of the relevant industrial associations.

In response to these pitfalls, we suggest four measures.

- The funding for R&D on CFBC and other clean coal technologies should be greatly increased.
- Government support to the absorption of imported technologies and dissemination of proven small-scale CFBC technologies should be increased.
- The support for the development/improvement of technology should be focused on smaller CFBC boilers with the first step to fully commercialize the 220 tph CFBC boiler manufacturing technology and demonstrate the indigenous 420 tph CFBC reheat boiler technology.
- Co-operation among industry, universities and research institutes should be strengthened through better institutional arrangement and regulatory framework.

It is also important that government support for the demonstration and commercialization of CFBC technologies be increased. In the past, the development of CFBC technology has been seriously affected by a lack of government support for the demonstration and commercialization of locally developed technologies. This situation should be avoided. Finally, only those projects which have a good chance of success should be openly appraised and given sufficient supports. Scarce resources should not be wasted on over-ambitious projects.

4.2 FACILITATING THE RESTRUCTURING OF CHINA'S BOILER MANUFACTURING SECTOR

It is anticipated that substantial restructuring will be taking place in China's boiler sector. China has demonstrated a number of comparative advantages in the boiler manufacturing, including low labor costs, relatively high mechanical engineering and processing capacity and comprehensive options for materials and components. For these reasons leading international CFBC boiler manufacturers such as FWC have started to subcontract Chinese major boiler manufacturers, for example SBWL and HBC, in producing the boiler islands for their projects in China and in some other Asian countries.

Rational industrial restructuring is essential to provide a suitable environment for boiler manufacturers to be willing and able to invest in technological innovation. It is essential for relevant government agencies at the local level to strictly enforce the boiler manufacture license requirement and technological standards. The ongoing government campaign to crack down on local protectionism will also help to remove

the local safety nets for over 1000 low-tech and illegal boiler producers and ultimately phase them out. With the social safety system taking shape, those loss-making boiler works should either go bankrupt or be acquired by other companies. Relevant government agencies might play a proactive role in fostering the widespread mergers and acquisitions (M&A) of insolvent boiler producers by stronger players by formulating preferential policies, setting dispute resolution rules and publishing neutral, objective technological and market information.

Boiler manufacturing is a labor-intensive industry. China will very probably become the global center of boiler manufacturing. There might be two scenarios for this. One is that one or two leading Chinese power generation equipment manufacturers (including boiler production) effectively compete with a few international players for both domestic and international utility boiler markets. The second scenario is that Chinese boiler manufacturers will become subsidiaries of leading multinational corporations in manufacturing utility boilers for the global market. To realize the first scenario, government will play a vital role to proactively foster the consolidation of China's boiler manufacturing sector through merger and acquisition.

With China's WTO accession, the pace of forming the social safety net will be increasing. Meanwhile, the interactions of local governments with local boiler works will be reduced gradually. More and more uncompetitive boiler manufacturers will go bankrupt due to the removal of the protection network. Furthermore, a wave of merge and acquisition will emerge in the course of the boiler sector restructuring. Those who effectively acquire external technology capacity could be winners of the forthcoming transformation.

The government should play a proactive role in making the industrial restructuring process a smoother one rather than a very painful and costly one by nurturing industrial alliance, integration of technical capacities in boiler manufacturers, etc. The role of government should be shifted away from direct intervention in the business operation of boiler manufacturers to enhancing the enforcement of environmental and energy regulations, formulation and implementation of credible policies, wide dissemination of neutral technology and market information, and public-private partnerships. The governmental role should be primarily accomplished through affecting the market demands rather than shaping the supply side directly.

Dismantling the local protectionism and fostering the formation of nation-wide market for environmentally sound boilers have proven to be preconditions for rational industrial transformation. So far, local protectionism has been widespread. Local authorities encourage the building-up of local protectionism aimed at protecting local products and technologies from competitions from outside regions. To some extent, local protection activities help increase revenues or subsidizing operational funds of a few local government departments. The actual results are twofold: additional market penetration costs for outside products and technologies that usually are more competitive; expanding markets for inefficient and poor quality products and technologies. The small amount of additional local revenues is at the huge cost.

The boiler products manufactured by the leading boiler companies have been inspected by the State Administration of Quality, Technical Supervision, and Quarantine and are awarded production licenses. Although state policy allows the boilers to be sold across the country without further test and verification, however, local governments set up their own requirements for local market penetration permits and charge additional fees for this process.

4.3 PROMOTING COOPERATION AND INTEGRATION BETWEEN LEADING TECHNOLOGY DEVELOPERS AND CFBC BOILER MANUFACTURERS

To confront the competition from multinational corporations, it is vital to vigorously foster strategic alliance and cooperation between leading domestic CFBC technology developers and boiler manufacturers. At this stage, government support for CFBC technology scaling-up and improvement might be good starting point for nurturing the long-term partnerships.

4.4 IMPROVING POLICY FORMULATION, IMPLEMENTATION AND EVALUATION PROCESS

Changing the Policy Formulation Process

It is essential to adopt a more participatory policy formulation process. If the policy should be better implemented, to involve more enterprises, not only the major industries, in the early stage of policy formulation processes are vital. First, the political willingness to do so is prerequisite. Second, cost-effective ways to do so are vital as well.

The increasingly transparent and participatory policy formulation process will also allow the affected industry to better prepare themselves for the future implementation.

Special attention should be given to small and medium-sized enterprises. If resources and time allow, cost-benefit analysis (CBA) should be carried out to assess the implications for SMEs to comply with the respective policy. It is also important to formulate the policy based upon accurate and timely information.

Enhancing the Monitoring and Evaluation of Policy Implementation

At present, there have been hardly effective mechanisms to monitor and report the actual implementation of the policies. The evaluation of policy implementation is for the most part on an ad hoc basis and carried out by some research institutes. This has prevented the policies from being constantly adjusted and improved.

It is interesting to mention leading boiler manufacturers, such as Shanghai Boiler Works, Ltd. have paid much attention to accessing policy and market information. However, smaller and remotely located factories, for example Sichuan Boiler Works, encounter more difficulty in having a complete and swift access to government policy.

SECTION 5: CONCLUSION

Before concluding, it is important to emphasize that the main problem faced by the producers of CFBC boilers is not the access to production technology. As mentioned earlier, Chinese boiler manufactures have been able to obtain technology to produce these boilers from a number of global leaders as well as domestic technology sources for CFBC boilers with capacity up to 200 tph. The problem is that these boilers are too costly for most users and the environmental policy has not created sufficient incentive for their introduction. As mentioned above, the cost of these boilers is high because the production has high import content. The cost can be brought down if the import content is reduced through increased indigenization of production.[□] This will require a greater degree of technology absorption than achieved in the past. The manufacturing facilities of the boilers produced will also have to be upgraded.

We suggest that both the technology and environmental policies should be directed towards reducing the cost, and increasing the demand for CFBC boilers. We recommend that the policies focus on:

- Substantially increasing the government support to R&D and demonstration activities for CFBC and other clean coal technologies.
- Promoting the local development, demonstration and commercialization of smaller, low cost CFBC boiler technology with a capacity up to 410 tph. China's chances of developing technology for large CFBC boilers are small. Therefore, the scarce governmental resources should not be "wasted" on the development of technology for large CFBC boilers. The governmental support should be focused on a limited number of "viable" projects.
- Increasing the diffusion of CFBC boilers. The technology policies should aim to reduce the cost of production through increased absorption of imported technology and indigenization of production and improvement of domestic CFBC technology. Environmental policies should focus on enforcement of regulations, which would create a demand for CFBC boilers and other EST.
- More concerned government efforts in scaling up the indigenous CFBC boiler technology and importing advanced international technology.
- Promoting strategic alliance and cooperation between leading CFBC technology developers and boiler manufacturers.

□ The cost of power equipment produced in China is much lower than imports. See: Razavi (undated), op.cit.
(1)

REFERENCES

- Chinese Academy of Engineering. 2001. Means of Technology Development for More Efficient and Cleaner Combustion of Medium-small sized Boilers. Beijing: Chinese Academy of Engineering.
- Global Environment Facility. 1996. China Efficient Industrial Boilers. Project Document. Washington DC: World Bank.
- Jiang Minhua. 2000. CFBC Boilers in China - Present and Future.
- Jin Yunhui, Liu Xue. 1999. Clean Coal Technology Acquisition: Present Situation, Obstacles, Opportunities and Strategies for China. Final Report to CCICED Working Group on Trade and Environment. August 1999.
- Ma Chi, Shi Han 2001. A Few Key Science and Technology Breakthroughs in China's Energy Sector. Research Paper No. 486 (Chinese only). Beijing: China Research Center for Science and Technology Development.
- Takahsshi M. 2001. World Bank Group's Energy and Environmental Strategy and Clean Cola Program. Washington DC: World Bank.
- Tschanun I., Wihann G. 1997. Coal fired Circulating Fluidized Bed Steam Generators for a Paper Mill in China; Power-Gen Asia 97. Conference Papers: Vol. I, pp 167-174. Singapore, 9-11 September 97.
- United Nations Development Programme. 1999. Report on Development of CFBC Technology in China (Coal Program-UNDP/CPR/91/212). Beijing: UNDP China
- World Bank. 2001. Policy Recommendations to SDPC Supporting Deployment of Clean Coal technologies in China. Washington DC: World Bank.

APPENDIX A

A1. LIST OF BOILER MANUFACTURERS VISITED

1. Harbin Boiler Co., Ltd.
2. Shanghai Boiler Works Co., Ltd.
3. Dongfang Boiler Works Co., Ltd.
4. Sichuan Boiler Works
5. Babcock & Wilcox Beijing Company Ltd. (BWBC)
6. Hangzhou Boiler Works Co., Ltd.
7. Wuxi Boiler Works
8. Jinan Boiler Group Co., Ltd.
9. Changchun Boiler Manufacture Co., Ltd.
10. Changchun Tian Ye Auto-Control Equipment Co., Ltd.
11. Yingkou Luyuan Boiler & Crane Co., Ltd.

A2. LIST OF CFBC BOILER TECHNOLOGY DEVELOPMENT INSTITUTIONS INTERVIEWED

Department of Thermal Engineering
Tsinghua University

Institute of Engineering Thermophysics (IET)
Chinese Academy of Sciences

Thermal Power Research Institute
State Power Corporation

Department of Energy Engineering
Zhejiang University

Department of Thermo-Energy Engineering
Harbin Institute of Technology

Harbin Power System Engineering & Research Institute (CHPI)

A3. LIST OF GOVERNMENT POLICIES AFFECTING THE DIFFUSION OF CFBC BOILER TECHNOLOGY

1. Jinan Mingshui Thermal Power Co., Ltd.
2. Shangdong Lingzi Coal Mine Power Plant
3. Dalian Tisong Plywood Co., Ltd.
4. Dalian Sanding Light Industrial Machine Co., Ltd.

APPENDIX B: CFBC BOILER UNITS IN CHINA LARGER THAN 50 MWE

CASE STUDY ON DEVELOPMENT OF CIRCULATING FLUIDIZED-BED COMBUSTION BOILERS IN CHINA

Year of commission	Plant Name	Location	No. of Units	Capacity (MWe)	Amount paid to CFBC boilers	Boiler Supplier	Fuel
1995	Panjin Liaohu Thermal Power Co.	Panjin, Liaoning	1	55		FWEC	Bituminous coal
1995	Dalian Industrial Chemical Co.	Dalian, Liaoning	2	50		Ahlstrom Pyropower Inc	
1996	Gaoba Power Plant	Neijiang, Sichuan	1	100		Ahlstrom Pyropower Inc	
1996	Hangzhou Xielian Thermal Power Corporation	Hangzhou, Zhejiang	1	50		Ahlstrom Pyropower Inc	
1996/1997	Ningbo Zhonghua Paper Corporation	Ningbo, Zhejiang	2	50		DFBW	Sub-bituminous coal, paper mill sludge
1998	Aixi Thermal Power Plant	Fuling, Sichuan	1	50			
1998	Dalian Xianhai Thermal Power Plant	Dalian, Liaoning	2	50		FWEC/HBC	Bituminous coal
1999	Zhenhai Power Plant	Ningbo, Zhejiang	2	50	\$23.722 million	FWEC	Petro-coke
2000	Yibin Power Plant	Yibin, Sichuan	1	100		DFBW	Meager coal
2001	Shanxi Zhenxing Power Plant	Shanxi	1	55		JBW	Middlings
2001	Shijiazhuang Power Plant	Shijiazhuang, Hebei	4	100		DFBW	Meager coal
2001	Baoding Power Plant	Baoding, Hebei	2	110		DFBW	Meager coal
2001	Sinopec Jingling Petrochemical Co.	Nanjing, Jiangsu	2	50		FWEO	Coal, petro-coke
	Baima Power Plant (planned)	Heijiang, Sichuan	1	300	\$30 million	FWC or Alstom	Anthracite